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Review

The French–Canadian data set of Demirjian for dental age estimation: A systematic review and meta-analysis

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ABSTRACT

Background: Estimation of age of an individual can be performed by evaluating the pattern of dental development. A dataset for age estimation based on the dental maturity of a French–Canadian population was published over 35 years ago and has become the most widely accepted dataset. The applicability of this dataset has been tested on different population groups.
Aim: To estimate the observed differences between Chronological age (CA) and Dental age (DA) when the French Canadian dataset was used to estimate the age of different population groups.
Materials and methods: A systematic search of literature for papers utilizing the French Canadian dataset for age estimation was performed. All language articles from PubMed, Embase and Cochrane databases were electronically searched for terms 'Demirjian' and 'Dental age' published between January 1973 and December 2011. A hand search of articles was also conducted.
Results: A total of 274 studies were identified from which 34 studies were included for qualitative analysis and 12 studies were included for quantitative assessment and meta-analysis. When synthesizing the estimation results from different population groups, on average, the Demirjian dataset overestimated the age of females by 0.65 years (−0.10 years to +2.82 years) and males by 0.60 years (−0.23 years to +3.04 years).
Conclusion: The French Canadian dataset overestimates the age of the subjects by more than six months and hence this dataset should be used only with considerable caution when estimating age of group of subjects of any global population.
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1. Introduction

Age estimation based on the stage of dental development has been widely reported in the literature, which has been established as a reliable method for estimating the age of people with unknown birth records.[1–3] Demirjian and co-workers derived dental maturity scores by evaluating the dental development of 1446 boys and 1482 girls aged 2–20 years belonging to a French–Canadian population. A classification system was also developed based on the stage of development of the crown and the root. The stages were expressed in letters representing an ordinal or ranking scale and the eight stages were designated as A–H.[3]

With the intention of improving the overall accuracy of the system, their work was updated in 1976 by increasing the sample size to incorporate dental maturity scores for additional tooth developmental stages, for example, stage A of the first premolar and stage C of the central incisor. As a consequence, this resulted in changes to the maturity scores. In addition, dental maturity

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scores based on a four-teeth system were added to the originally proposed seven-teeth system. This enables the observer to derive an age when a limited number of teeth are available and could be performed just from a periapical radiograph. The maturity scores thus proposed have been tested on different ethnic and geographic population groups in order to determine its applicability.[3,4] When the data set was used on different populations, overestimation of the age was observed, that is, the subjects under study were dentally advanced in development compared to the French–Canadian children. It was conjectured that "the scores for the stages will not vary too much between populations, but that the maturity standards may change appreciably" (Demirjian and Goldstein, 1976 p. 420). Although variations are anticipated when using the French–Canadian data set, a number of authors, in the absence of a local Reference Data Set, have used the French–Canadian information. The quest to evaluate the applicability of this data set still continues for unstudied populations. Therefore, following a systematic review of the literature, a retrospective analysis was conducted with the aim of answering a question: What is the accuracy and what are variations in age estimation in different ethnic and racial groups using the French–Canadian data set?

2. Materials and methods

2.1. Selection of studies

Articles published in English and other languages between January 1973 and December 2011 were searched. The selection of papers suitable for inclusion in the review was independently carried out by two of the authors (JJ and HMW).

2.2. Inclusion criteria

Original research papers that used Demirjian's data set for age estimation on healthy subjects, either for validating its applicability or for creating an adopted data set, were included in the study. Studies expressing the results in mean differences alone were included as it was intended to analyse the exact degree of variation between the chronological age (CA) and the estimated dental age (DA).

2.3. Exclusion criteria

As this analysis is performed to generalise the results in mean difference, those studies expressing age estimation results in median or in percentages were excluded. Furthermore, studies conducted on subjects who were physically or medically compromised and those with developmental anomalies were excluded. In order to be able to perform robust analysis on the generalised applicability of the data set, studies performed on only a fewer teeth and those exclusively on third molars were also excluded. It should be noted that the original system of assessment proposed by the authors excluded third molars.

2.4. Types of participants

Studies that recruited healthy subjects aged between 2 and 21 years were included.

2.5. Electronic searches

PubMed, EMBASE and COCHRANE databases were searched for the terms 'Demirjian' and 'dental age'.

2.6. Hand searching

The following journals were hand searched with similar search terms to locate any relevant articles: Forensic Science International, Journal of Forensic Sciences, Journal of Forensic Odontostomatology, International Journal of Legal Medicine and International Journal of Paediatric Dentistry. The journals were shortlisted on the basis of the number of studies published relevant to 'dental age estimation'. The reference lists of the selected articles were further scrutinised to identify additional studies.

3. Results

3.1. Results of the search

A total of 274 articles including five foreign language articles (Hungarian, German, French, Senegalese and Chinese) were retrieved through electronic searching. The numbers of articles retrieved from PubMed and EMBASE were 122 and 152, respectively. There were no articles available from the COCHRANE databases and through hand searching.

During the selection process, any disagreement in the selection of articles between the review authors was resolved by discussion. Foreign language articles were translated to English with the help of a translator. From the five foreign language articles, only two met the inclusion criteria (Chinese and Senegalese). From the reference list, one study published in Croatian language was included. It was later found that the study reported the observed variations as median difference; hence, it was excluded.[5] Finally, 34 studies were available for the qualitative analysis, from which 12 studies were further scrutinised for quantitative synthesis and meta-analysis. The literature search and study selection process are described in Fig. 1.

3.2. Participants

A total of 19,599 participants (9708 male and 9891 female), aged between 2 and 21 years, were recruited in the analysis.

3.3. Design, methods and outcome measures

All of the studies reported the mean age difference, that is, the difference between the estimated DA and the CA (or vice versa). The estimated age differences, if in months, were then converted to decimal years.[6,7] For the studies in which the age estimation differences were not presented in the text, but in a table, the mean differences were obtained by carefully examining the table values.[8–14] Most of the studies used the original version of the French–Canadian data set for age estimation.[1] Only three studies[9,11,15] used the updated version of the data set.[4]

3.4. Qualitative analysis

Overestimation of age was commonly reported when using the Demirjian data set.[9–11] Conversely, underestimation of the age was observed only in the Venezuelan subjects[16] and western Chinese males.[17] A study conducted on northern Indian subjects was the only one to demonstrate accurate age estimation for all the age groups and both sexes; the overall mean difference for males was 0.13 years and for females, it was 0.10 years.[12]

When analysing the age estimation results for the global population, the variations in the estimated age ranged from −0.08 years to +3.04 years for males and −0.10 years to +2.82 years for females (Figs. 2 and 3). Minimal differences were observed in the western Chinese subjects; there was a mean difference of −0.08

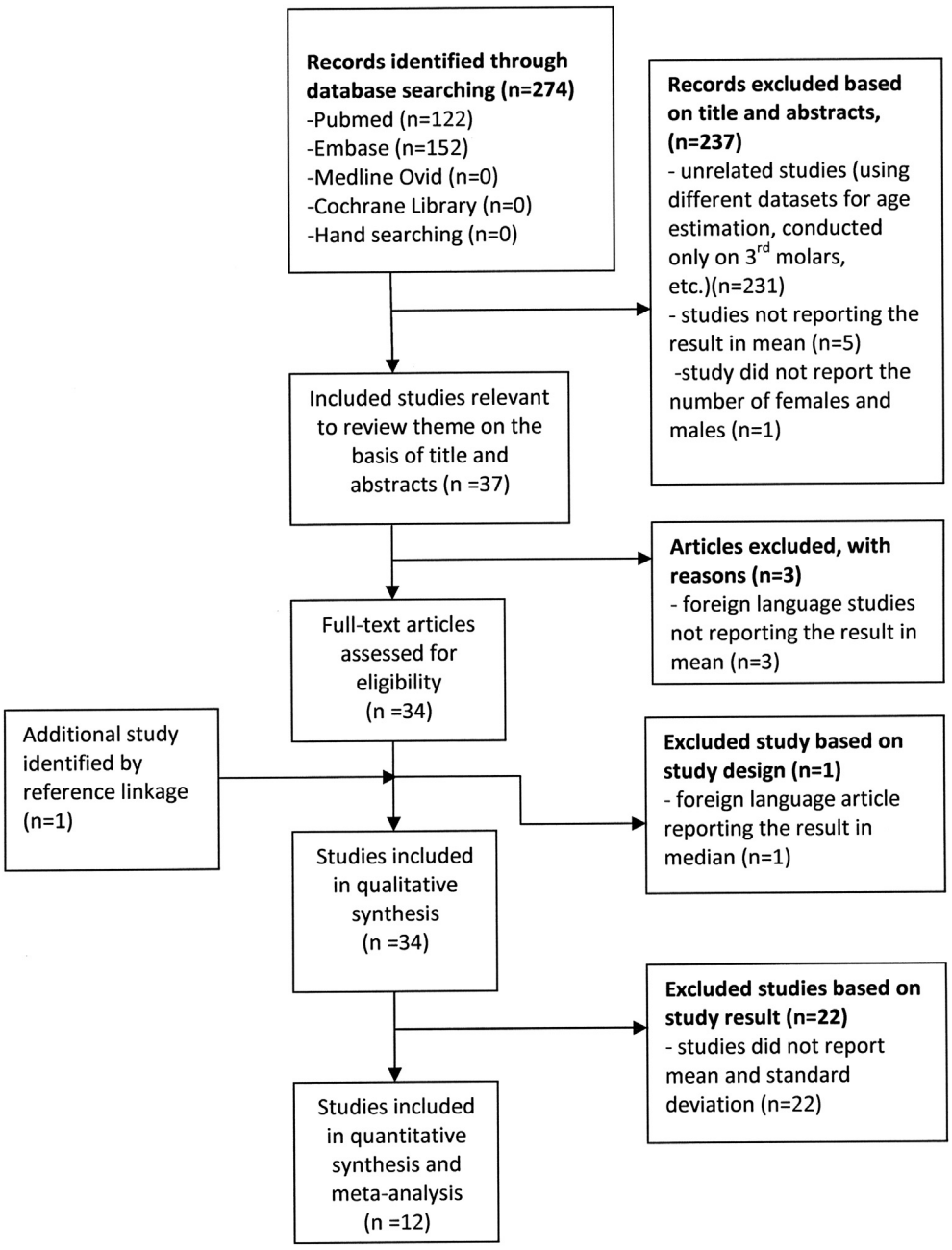

Fig. 1. Flowchart describing the literature search and study selection process.

years for males and +0.15 years for females.[17] Maximum differences of +3.04 years for males and +2.82 years for females were reported for the southern Indian subjects.[18] On average, Demirjian's data set overestimated the age of females by 0.65 years (−0.10 years to +2.82 years) and males by 0.60 years (−0.23 years to +3.04 years). Variations in the estimated age using Demirjian data set among the various ethnic and population groups are shown in Table 1.

3.5. Quantitative analysis

Quantitative synthesis and meta-analysis of the studies demonstrated significant variation in the estimated age among different population groups ($p < 0.0001$) resulting in overestimation of the age of males and females by 6 months (Figs. 4 and 5). Underestimation of age was observed only in the Venezuelan study, although it demonstrated a higher standard deviation for the mean age difference.[16] The maximum mean difference was observed in the Indian subjects[18]; the minimum mean difference and standard deviation was observed in the Indian,[19] UK Caucasians[20] and UK mixed ethnic groups of subjects.[21]

4. Discussion

Studies that used the French–Canadian data set and expressed the age estimation results in mean differences were included so as to be able to analyse the overall difference in DA among the various population groups. The studies included thus belong to two categories: (i) studies that just evaluated the applicability of the Demirjian data set and (ii) studies that adopted Demirjian's

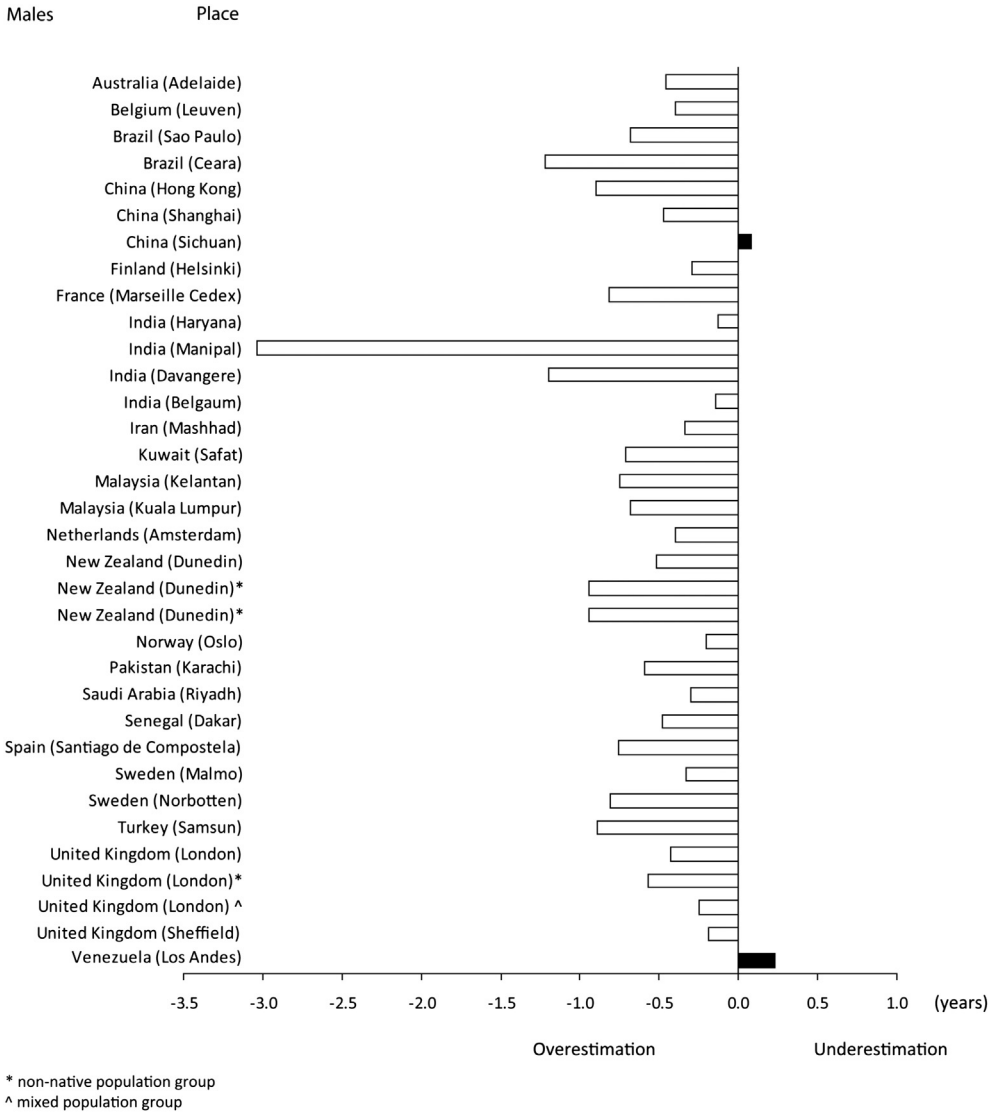

Fig. 2. Variations in the age (CA-DA) for males among different populations using the French Canadian dataset.

maturity scores for use in their population, following inaccuracy in the estimated age. There remains some degree of confusion caused by authors in calculating the difference between the CA and DA. This has even resulted in misinterpretation of data.[21] All the studies calculated the age difference as DA–CA except for four that followed the CA–DA calculation.[13,14,22,23] As CA is a 'gold standard' data, we have established CA–DA as the preferred format for reporting the age difference.

The dental maturity scores derived from the French–Canadian population were applicable for subjects only up to 16 years of age as their evaluation was confined to the development of the permanent second molars. The number of teeth included in the Demirjian data set is a possible limitation as it extends only up to 15.5 years, when the lower left second molar (LL7) completes its development, thus limiting the DA estimations to <16 years (of age).[24] The legal systems in most of the countries have identified 10, 13, 16 and 18 years as important ages for conviction for criminal charges. Hence, there is a demand for accurate age estimation in these age groups. As all of the age groups, up to 16 years, were covered in the French–Canadian dental maturity scores, investigators were confronted with extension of age estimates beyond 16 years. This has been performed by evaluating the dental maturity status of the third molars followed by statistical modification of the dental maturity scores originally proposed by Demirjian and co-workers. Similar analyses were conducted on Finnish,[9] Indian,[25] French[26] and a mixed ethnic group of subjects.[27] The accuracy of the data set derived by this method, however, remains unclear. It is of interest that there has not been a formal validation using a 'blind' test of the applicability of the French–Canadian data set to French–Canadian subjects not forming part of the data set.

Studies using the French–Canadian dental maturity scores have frequently reported inaccurate age estimations. Different postulates have been put forth to explain the reasons for these variations. Detrimental nutritional condition and poor socioeconomic status have been reported to affect dental and skeletal growth resulting in inter-individual variability.[18] Great emphasis has been placed on inter-ethnic variations in dental development, particularly between the French–Canadian population and other population groups.[28] However, this postulate was refuted and was suggested that the differences were more likely due to method error rather than ethnic variations although these authors did not give any data to support this criticism.[7] Although overestimation of age has been

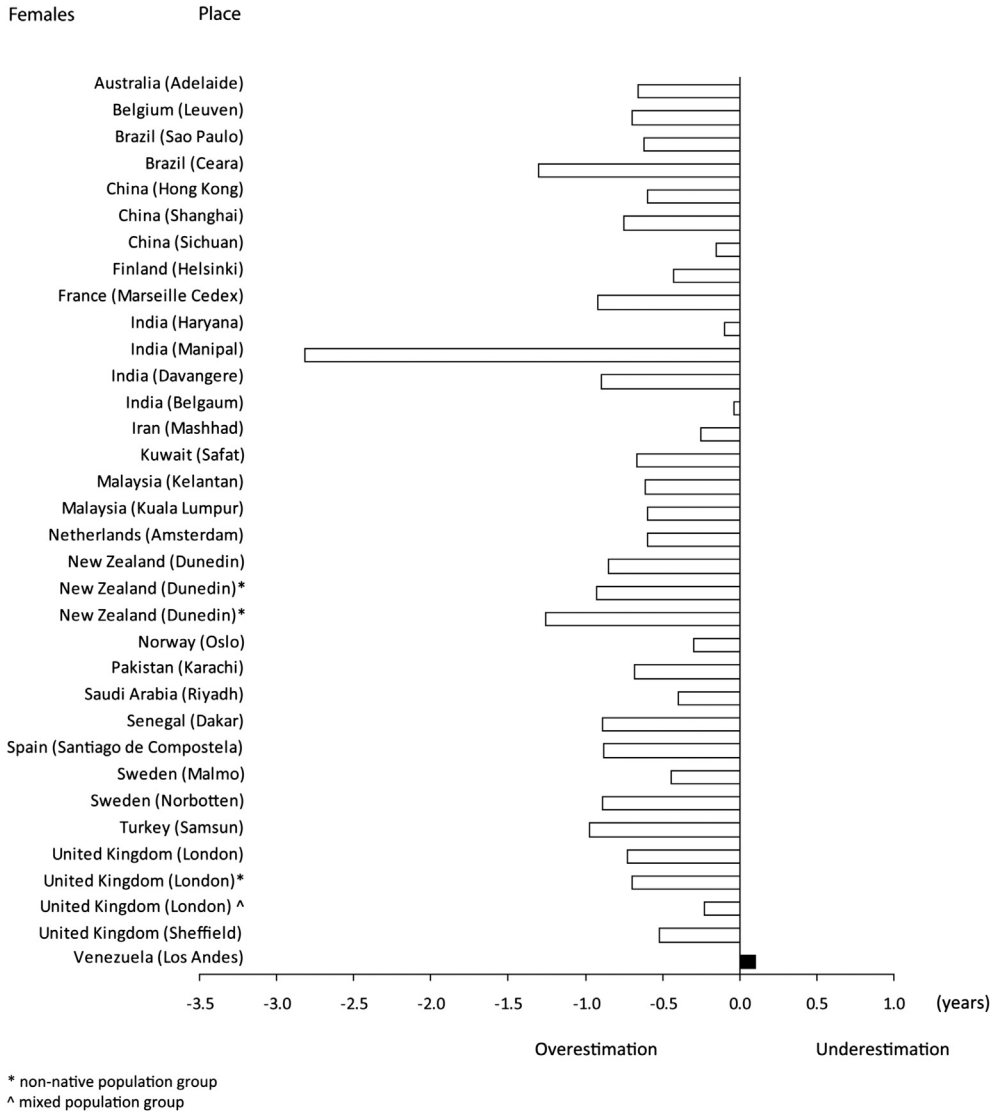

Fig. 3. Variations in the age (CA-DA) for females among different populations using the French Canadian dataset.

frequently reported, underestimations have also been reported for a few populations.[16,17] Investigators have also demonstrated age estimation differences between females and males and between older and younger individuals. A high level of accuracy has been reported using the French–Canadian data set when applied to young individuals. It has been suggested that the high accuracy was related to the large number of tooth developmental stages in the younger dentition covering a shorter time span.[7]

The originally proposed dental maturity scores have been adjusted for use in different population groups.[3] Statistical methodologies including linear regression and non-linear regression were performed to modify the maturity scores of the French–Canadian subjects.[22,29] It has been reported that construction of population-specific tables using cubic function would allow accurate age assessments (Teivens and Mornstad, 2001a).[30] Few investigators have used Bonferroni corrections and converted the maturity scores into DA. It was claimed that this method minimised the calculation error by directly obtaining the DA for the corresponding stage of tooth development (Willems et al., 2001).[31] Statistical modifications have drawbacks; the least is that the resulting scores are adjusted values of an existing data set and not a true derivative for the population.

Varying age estimation results were observed between the population groups living in different countries, for example, Australia,[13] Great Britain[21] and Kuwait[29] and between different regions of the same country, for example, northern India[12] and southern[18] and southern China[6] and western China.[17] Similar variations were also observed among population groups living within a confined geographical region. In our study, three reports that were independently performed in the southern Indian regions of Manipal, Davangere and Belgaum were analysed. These regions are all within 200 miles and the studies are conducted on ethnically similar groups of subjects aged between 5 and 15 years. All three studies reported overestimation of DA with an overall mean overestimation of 2.82 years for females and 3.04 years for males,[18] 0.90 years for females and 1.20 years for males[19] and 0.04 years for females and 0.14 years for males, respectively.[32] This clearly indicates that there is a great degree of variation; however, there is no obvious explanation to support the reasons for these observed differences. A study used the French–Canadian data set to compare the dental maturity of subjects from eight different countries and found that the Australians had the earliest dental maturation while Koreans had the slowest.[27] Similarly, significant differences in the dental maturity among Korean and Swedish subjects have been

Table 1
Age estimation results among different population groups using the French Canadian dataset.

Country	Author	Place	Ethnicity[d]	Sample size			Age (years)	Statistical adjustments	Age estimation difference CA-DA (years)	
				Total	Females	Males			Females	Males
Australia[13]	McKenna et al., 2002	Adelaide	White, other	615	288	327	4.9 to 16.9	N/A	−0.51[b]	−0.30[b]
Belgium[31]	Willems et al., 2001	Leuven	White, other	2116	1029	1087	3 to 18	Bonferroni correction	−0.70	−0.40
Brazil[43]	Eid et al., 2002	Sao Paulo	Not stated	689	321	368	6 to 14	Regression analysis	−0.62	−0.68
Brazil[44]	Maia et al., 2010	Ceara	Not stated	1491	670	821	7 to 13	Regression analysis	−1.30	−1.22
China[6]	Davis & Hagg, 1994	Hong Kong	Chinese	204	101	103	5 to 7	N/A	−0.58[a]	−0.91[a]
China[45]	Jayaraman et al., 2011	Hong Kong	Chinese	182	91	91	3 to 16	N/A	−0.62	−0.36
China[23]	Tao et al., 2007	Shanghai	Chinese	828	549	279	11 to 19	N/A	−0.75[b]	−0.47[b]
China[17]	Chen et al., 2010	Sichuan	Chinese	445	217	228	8 to 16	Regression analysis	−0.15	0.08
Finland[9]	Nystrom et al., 1986	Helsinki	White, other	738	349	389	2.5 to 16.5	Regression analysis	−0.43[b c]	−0.29[b c]
France[22]	Foti et al., 2003	Marseille Cedex	White, other	100	49	51	6 to 21	Multiple linear regression	−0.92[b]	−0.82[b]
India[18]	Koshy & Tandon, 1998	Manipal	Asian, Indian	184	93	91	5 to 15	Regression analysis	−2.82	−3.04
India[19]	Prabhakar et al., 2002	Davangere	Asian, Indian	151	78	73	6 to 15	Regression analysis	−0.90	−1.20
India[32]	Hegde & Sood, 2002	Belgaum	Asian, Indian	197	94	103	6 to 12	N/A	−0.04	−0.14
India[12]	Rai et al., 2007	Haryana	Asian, Indian	425	207	218	5 to 17	N/A	−0.10[b]	−0.13[b]
Iran[46]	Bagherpour et al., 2010	Mashhad	Not stated	311	141	170	6 to 13	N/A	−0.25	−0.34
Iran[47]	Bagherian & Jadeghi, 2011	Rafsanjan	Not stated	519	264	255	3.5 to 13.5	N/A	−0.15	−0.21
Kuwait[29]	Qudeimat & Behbehani, 2009	Safat	Not stated	509	246	263	3 to 14	Non-linear regression analysis	−0.67	−0.71
Malaysia[48]	Mani et al., 2008	Kelantan	Asian, other	428	214	214	7 to 15	N/A	−0.61	−0.75
Malaysia[10]	Nik-Hussein et al., 2010	Kuala Lumpur	Asian, other	991	504	487	5 to 15	N/A	−0.61[b]	−0.68[b]
Netherland[49]	Leurs et al., 2005	Amsterdam	White, other	451	226	225	3 to 17	Logistic regression analysis	−0.60	−0.40
New Zealand[11]	Moananui et al., 2008	Dunedin	White, other	740	394	346	3 to 14	N/A	−0.64[b c]	−0.52[b c]
New Zealand[11]	Moananui et al., 2008	Dunedin	Not stated	461	220	241	3 to 14	N/A	−0.93[b c]	−0.84[b c]
New Zealand[11]	Moananui et al., 2008	Dunedin	Not stated	130	72	58	4 to 13	N/A	−1.26[b c]	−1.15[b c]
Norway[15]	Nykanen et al., 1998	Oslo	White, other	261	128	133	5.5 to 12.5	N/A	−0.30[c]	−0.20[c]
Pakistan[14]	Sukhia et al., 2010	Karachi	Asian, Pakistani	882	427	455	7 to 14	N/A	−0.68[b]	−0.59[b]
Saudi Arabia[50]	Al-Emran, 2008	Riyadh	Not stated	490	225	265	8.5 to 17	Logistic regression analysis	−0.40	−0.30
Senegal[51]	Ngom et al., 2007	Dakar	Black, African	200	101	99	6 to 14	Linear regression analysis	−0.89	−0.48
Spain[16]	Cruz-Landeira et al., 2010	Santiago de Compostela	Not stated	308	151	157	2 to 18	Regression analysis	−0.88	−0.76
Sweden[7]	Hagg & Matsson, 1985	Malmo	White, others	300	150	150	3.5 to 12.5	N/A	−0.61[b a]	−0.51[b a]
Sweden[52]	Staaf et al., 1991	Norrbotten	White, others	541	270	271	5.5 to 12.5	N/A	−0.89	−0.81
Turkey[8]	Tunc & Koyuturk, 2008	Samsun	Not stated	900	457	443	4 to 12	N/A	−0.91[b]	−0.74[b]
Turkey[53]	Celikoglu et al., 2011	Ataturk	Not stated	807	366	441	7 to 15	N/A	−0.45	−0.85
United Kingdom[54]	Liversidge et al., 1999	London	White, British	256	131	125	4 to 9	N/A	−0.73	−0.43
United Kingdom[54]	Liversidge et al., 1999	London	Asian, Bangladeshi	265	132	133	4 to 9	N/A	−0.70	−0.57
United Kingdom[20]	Davidson & Rodd, 2001	Sheffield	White, British	81	42	39	Less than 16 years	N/A	−0.52	−0.19
United Kingdom[21]	Maber et al., 2006	London	White, British and Asian, Bangladeshi	946	491	455	3 to 17	N/A	−0.23	−0.25
United States[55]	Weddel & Hartsfield, 2011	Indianapolis	White, others	257	117	140	5 to 17	N/A	−0.61	−0.57
Venezuela[16]	Cruz-Landeira et al., 2010	Los Andes	Not stated	200	103	97	2 to 18	N/A	0.10	0.23
Total	–	–	–	*19,599*	*9708*	*9891*	–	–	*−0.65*	*−0.60*

[a] Converted value.
[b] Table value calculation.
[c] Updated dataset (Demirjian & Goldstein, 1976).
[d] Classification system adopted from the UK National Statistics (2001).

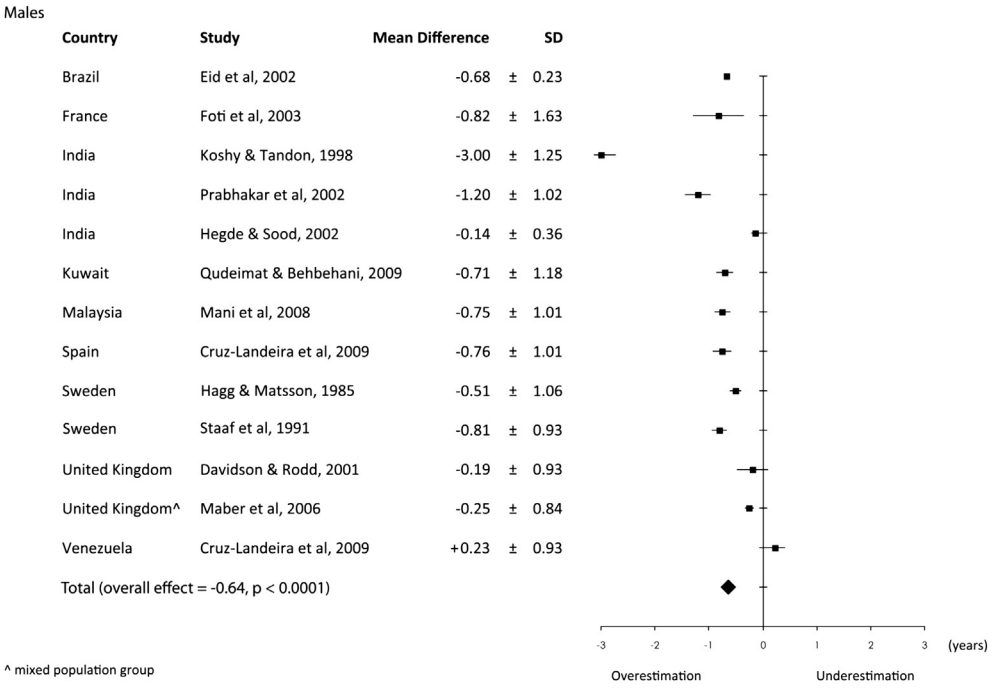

Fig. 4. Forest plot of mean differences in the age (CA-DA) among males derived from the French Canadian dataset.

demonstrated.[33] Conversely, a study reported minimal difference in the dental development of a group of subjects of Bangladeshi origin and British Caucasian origin living in the London area of the UK.[21] From these analyses, it is understood that variation in dental maturity exists between different population groups. When calculating CA, in most cases, the identity document serves as a gold standard for recording this data. A study conducted in the UK evaluated the dental development of children born in Somalia. As the reliability of the reported age is questioned, this particular data is excluded from the statistical analysis of our study.[20]

Genetic variations, socioeconomic status and environmental influences reportedly influence dental maturity. It has been agreed that the variations observed were further influenced by the methodology of the study and this includes the size and distribution of the sample, inter-individual variability, reliability of the examiner, scoring criteria and the statistical analyses that were performed. It is interesting to note that a secular trend in the development of the permanent teeth has been reported between subjects from two different decades.[28] The effect of this observation warrants further exploration as data from studies conducted in

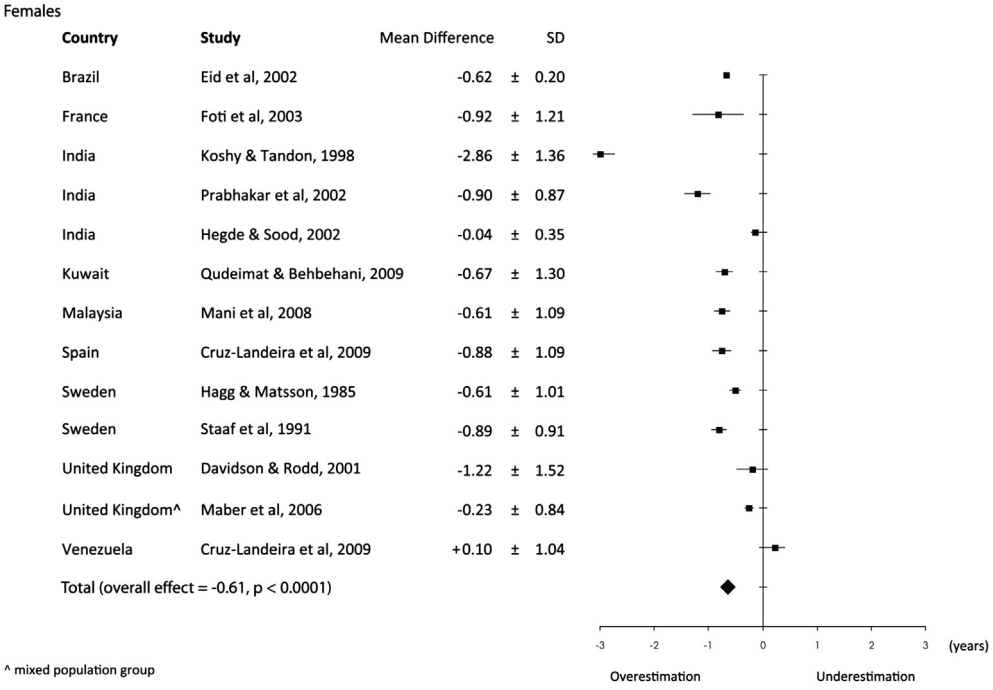

Fig. 5. Forest plot of mean differences in the age (CA-DA) among females derived from the French Canadian dataset.

different decades may show different results. It seems that most of the investigators have predominantly classified the subjects according to geographic region and only to a lesser extent, according to ethnicity. The current issues of globalisation and migration of human population make it difficult to estimate the extent to which ethnicity needs to be identified. In the current study, an attempt was made to identify the ethnicity of the subjects based on the classification system proposed by the Office of National Statistics in the U.K.[34] The ethnicities that were not included in the UK system, for example, the Hispanic and Arab, were marked as 'not stated', see Table 1. Currently, no universal consensus has been adopted to classify the identifiable human groups based on race and ethnicity. A country which is defined by a geographical boundary could contain different ethnic groups of varying genetic predispositions. Individual evaluations of these ethnic groups need to be performed to obtain a detailed understanding of dental growth among these groups. This approach was made clear by a study conducted in New Zealand, where age estimations were individually calculated on the native Maori, the Pacific Islanders and the children of European origin.[11] Furthermore, identification of human groups by tracing a 'family tree' allows understanding of genetic patterns of inheritance. This approach would facilitate the development of a classification system based on the ethnicity of the subjects and not on the geographic location.

The French–Canadian DA estimation method is based on the evaluation of dental development of seven mandibular teeth on the left side. Human remains recovered from a mass disaster where there has been loss of the mandible would not be amenable to age assessment using the Demirjian system.[35] Moreover, the 'seven teeth system' cannot be applied to subjects with bilaterally missing permanent mandibular teeth. A recently developed method allows the age estimation process to be performed on either the maxillary or mandibular dentitions or both. It is suggested that inclusion of an additional number of teeth in the analysis improves the overall accuracy of age estimation.[36] The maxillary dentition is usually not preferred for analysis due to the superimpositions of the hard and soft tissues onto the teeth, which makes the radiographic analysis challenging. It has been demonstrated that the downward positioning of the chin during panoramic image exposure results in minimal superimpositions and improves visualisation of the maxillary dentition.[37]

Age estimation results using the French–Canadian data set have been expressed in different ways. A study conducted in Poland demonstrated that the Demirjian data set overestimated the age of 77.5% of males and 81.7% of females.[38] A study on Hungarian subjects reported an overestimation through directly comparing the dental maturity scores of the French–Canadian data set.[39] For accurate age estimation, maturity scores of the Demirjian data set have been adopted to western Australian,[35] German[40] and Korean[41] populations. In the current study, quantitative synthesis was performed and only 12 studies reported the mean and the standard deviation. A further shortcoming is that the number of tooth developmental stages included in the study is often not reported. It is a major drawback that we excluded some papers on the account that they reported the results in median and in percentages. In those studies that reported mean, the analyses could have been elaborately performed if the standard deviation of the difference in DA were reported, individually for each age group and between the sexes. Demirjian's data set can be used to assess dental maturity at an individual level; however, it is inappropriate to estimate population differences.[42] We have provided a compilation of data from the studies that have used the French–Canadian data set for age estimation. The results can be overlooked by the variations in the reported studies including sample size, average age, mean, standard deviation and reliability scores of the examiners.

5. Conclusion

The French–Canadian data set has shown inconsistent age estimations on different ethnic and geographical population groups. The only study that demonstrated accuracy was based on Indian subjects for whom closer age estimates and minimal standard deviations on all the age groups and between the sexes are reported. The age estimation difference ranges from −0.10 years to 2.82 years for females and from −0.23 years to 3.04 years for males. By analysing the results from different countries, our study identified that the French–Canadian data set overestimated the age of the males and females on average by 6 months. Demirjian's data set should be used only with considerable caution when estimating the age of group of subjects of any global population.

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None.

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Conflict of interest
None.

References

1. Moorrees CF, Fanning EA, Hunt Jr EE. Age variation of formation stages for Ten permanent teeth. *J Dent Res* 1963;**42**:1490–502.
2. Haavikko K. Tooth formation age estimated on a few selected teeth. A simple method for clinical use. *Proc Finn Dent Soc* 1974;**70**:15–9.
3. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. *Hum Biol* 1973;**45**:221–7.
4. Demirjian A, Goldstein H. New systems of dental maturity based on seven and four teeth. *Ann Hum Biol* 1976;**5**:411–21.
5. Borcic I, Petrovecki M, Brkic H. Studies of two different methods for dental age estimation in Croatian children. *Acta Stomatol Croat* 2006;**40**:135–41.
6. Davis PJ, Hägg U. The accuracy and precision of the "Demirjian system" when used for age determination in Chinese children. *Swed Dent J* 1994;**18**:113–6.
7. Hägg U, Matsson L. Dental maturity as an indicator of chronological age: the accuracy and precision of three methods. *Eur J Orthod* 1985;**7**:25–34.
8. Tunc ES, Koyuturk AE. Dental age assessment using Demirjian's method on northern Turkish children. *Forensic Sci Int* 2008;**25**:23–6.
9. Nystrom M, Haataja J, Kataja M, Evalahti M, Peck L, Kleemola-Kujala E. Dental maturity in Finnish children, estimated from the development of seven permanent mandibular teeth. *Acta Odontol Scand* 1986;**44**:193–8.
10. Nik-Hussein NN, Kee KM, Gan P. Validity of Demirjian and Willems methods for dental age estimation for Malaysian children aged 5–15 years old. *Forensic Sci Int* 2010;**30**:208. e1-6.
11. TeMoananui R, Kieser JA, Herbison GP, Liversidge HM. Advanced dental maturation in New Zealand Maori and Pacific Island children. *Am J Hum Biol* 2008;**20**:43–50.
12. Rai B, Dhattarwal SK, Anand SC. Accuracy of Demirjian method for north Indian population. *Medico Leg Update* 2007;**7**:119–21.
13. McKenna CJ, James H, Taylor JA, Townsend GC. Tooth development standards for South Australia. *Aust Dent J* 2002;**47**:223–7.
14. Sukhia RH, Fida M, Azam SI. Dental age table for a sample of Pakistani children. *Eur J Orthodont* 2012;**34**:77–82.
15. Nykanen R, Espeland L, Kvaal SI, Krogstad O. Validity of the Demirjian method for dental age estimation when applied to Norwegian children. *Acta Odontol Scand* 1998;**56**:238–44.
16. Cruz-Landeira A, Linares-Argote J, Martínez-Rodríguez M. Dental age estimation in Spanish and Venezuelan children: comparison of Demirjian and Chaillet's scores. *Int J Leg Med* 2010;**124**:105–12.
17. Chen JW, Guo J, Zhou J, Liu RK, Chen TT, Zou SJ. Assessment of dental maturity of western Chinese children using Demirjian's method. *Forensic Sci Int* 2010;**197**:119. e1-4.
18. Koshy S, Tandon S. Dental age assessment: the applicability of Demirjian's method in south Indian children. *Forensic Sci Int* 1998;**94**:73–85.
19. Prabhakar AR, Panda AK, Raju OS. Applicability of Demirjian's method of age assessment in children of Davangere. *J Indian Soc Pedod Prev Dent* 2002;**20**:54–62.
20. Davidson LE, Rodd HD. Interrelationship between dental age and chronological age in Somali children. *Community Dent Health* 2001;**18**:27–30.
21. Maber M, Liversidge HM, Hector MP. Accuracy of age estimation of radiographic methods using developing teeth. *Forensic Sci Int* 2006;**15**:S68–73.

22. Foti B, Lalys L, Adalian P, Giustiniani J, Maczel M, Signoli M, et al. New forensic approach to age determination in children based on tooth eruption. *Forensic Sci Int* 2003;**132**:49–56.
23. Tao J, Wang Y, Liu RJ, Xu X, Li XP. Accuracy of age estimation from orthopantomograph using Demirjian's method. *Fa Yi Xue Za Zhi* 2007;**23**:258–60.
24. Peiris TS, Roberts GJ, Prabhu N. Dental age assessment: a comparison of 4- to 24-year-olds in the United Kingdom and an Australian population. *Int J Paed Dent* 2009;**19**:367–76.
25. Acharya AB. Age estimation in Indians using Demirjian's 8-teeth method. *J Forensic Sci* 2011;**56**:124–7.
26. Chaillet N, Demirjian A. Dental maturity in South France: a comparison between Demirjian's method and polynomial functions. *J Forensic Sci* 2004;**49**: 1059–66.
27. Chaillet N, Nyström M, Demirjian A. Comparison of dental maturity in children of different ethnic origins: international maturity curves for clinicians. *J Forensic Sci* 2005;**50**:1164–74.
28. Nadler GL. Earlier dental maturation: fact or fiction? *Angle Orthod* 1998;**68**: 535–8.
29. Qudeimat MA, Behbehani F. Dental age assessment for Kuwaiti children using Demirjian's method. *Ann Hum Biol* 2009;**36**:695–704.
30. Teivens A, Mornstad H. A modification of the Demirjian method for age estimation in children. *J Forensic Odontostomatol* 2001;**19**:26–30.
31. Willems G, Van Olmen A, Spiessens B, Carels C. Dental age estimation in Belgian children: Demirjian's technique revisited. *J Forensic Sci* 2001;**46**:893–5.
32. Hegde RJ, Sood PB. Dental maturity as an indicator of chronological age: radiographic evaluation of dental age in 6 to 13 years children of Belgaum using Demirjian methods. *J Indian Soc Pedod Prev Dent* 2002;**20**:132–8.
33. Teivens A, Mornstad H. A comparison between dental maturity rate in the Swedish and Korean populations using a modified Demirjian method. *J Forensic Odontostomatol* 2001;**19**:31–5.
34. United Kingdom National Statistics 2001, http://www.ons.gov.uk/about-statistics/classifications/archived/ethnic-interim/presenting-data/index.html [assessed 24.04.11].
35. Farah CS, Booth DR, Knott SC. Dental maturity of children in Perth, Western Australia, and its application in forensic age estimation. *J Clin Forensic Med* 1999;**6**:14–8.
36. Roberts GJ, Parekh S, Petrie A, Lucas VS. Dental age assessment (DAA): a simple method for children and emerging adults. *Brit Dent J* 2008;**204**:E7.
37. Moze K. Dental Age Assessment (DAA) in Trinidad and Tobago. Master of Science Dissertation, University of London; 2009.
38. Rozylo-Kalinowska I, Kiworkowa-Raczkowska E, Kalinowski P. Dental age in central Poland. *Forensic Sci Int* 2008;**30**:207–16.
39. Nyárády Z, Mörnstad H, Olasz L, Szabó G. Age estimation of children in southwestern Hungary using the modified Demirjian method. *Fogorvosi Szemle* 2005;**98**:193–8.
40. Frucht S, Schnegelsberg C, Schulte-Mönting J, Rose E, Jonas I. Dental age in southwest Germany. A radiographic study. *J Orofac Orthop* 2000;**61**:318–29.
41. Lee SE, Lee SH, Lee JY, Park HK, Kim YK. Age estimation of Korean children based on dental maturity. *Forensic Sci Int* 2008;**178**:125–31.
42. Liversidge HM. Interpreting group differences using Demirjian's dental maturity method. *Forensic Sci Int* 2010;**201**:95–101.
43. Eid RM, Simi R, Friggi MN, Fisberg M. Assessment of dental maturity of Brazilian children aged 6 to 14 years using Demirjian's method. *Int J Paed Dent* 2002;**12**:423–8.
44. Maia MC, Martins Mda G, Germano FA, Brandão Neto J, da Silva CA. Demirjian's system for estimating the dental age of northeastern Brazilian children. *Forensic Sci Int* 2010;**15**(200):e1–4.
45. Jayaraman J, King NM, Roberts GJ, Wong HM. Dental age assessment: are Demirjian's standards appropriate for southern Chinese children? *J Forensic Odontostomatol* 2011;**29**:22–8.
46. Bagherpour A, Imanimoghaddam M, Bagherpour MR, Einolghozati M. Dental age assessment among Iranian children aged 6–13 years using the Demirjian method. *Forensic Sci Int* 2010;**15**:e1–4.
47. Bagherian A, Sadeghi M. Assessment of dental maturity of children aged 3.5 to 13.5 years using the Demirjian method in an Iranian population. *J Oral Sci* 2011;**53**:37–42.
48. Mani SA, Naing L, John J, Samsudin AR. Comparison of two methods of dental age estimation in 7–15-year-old Malays. *Int J Paed Dent* 2008;**18**:380–8.
49. Leurs IH, Wattel E, Aartman IH, Etty E, Prahl-Andersen B. Dental age in Dutch children. *Eur J Orthod* 2005;**27**:309–14.
50. Al-Emran S. Dental age assessment of 8.5 to 17 Year-old Saudi children using Demirjian's method. *J Contemp Dent Pract* 2008;**9**:64–71.
51. Ngom PI, Faye M, Ndoye Ndiaye F, Diagne F, Yam AA. Applicabilite des standards de maturation de Demirjian chez des enfants Senegalais. *Dakar Médical* 2007;**52**:196–203.
52. Staaf V, Mörnstad H, Welander U. Age estimation based on tooth development: a test of reliability and validity. *Scand J Dent Res* 1991;**99**:281–6.
53. Celikoglu M, Cantekin K, Ceylan I. Dental age assessment: the applicability of Demirjian method in eastern Turkish children. *J Forensic Sci* 2011;**56**: S220–2.
54. Liversidge HM, Speechly T, Hector MP. Dental maturation in British children: are Demirjian's standards applicable? *Int J Paed Dent* 1999;**9**:263–9.
55. Weddell LS, Hartsfield Jr JK. Dental maturity of Caucasian children in the Indianapolis area. *Pediatr Dent* 2011;**33**:221–7.